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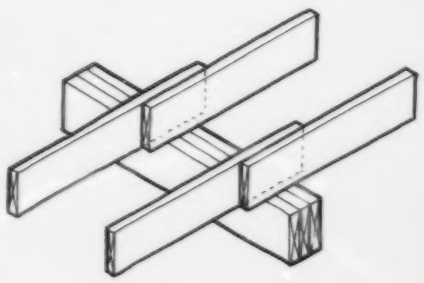
BUILDERS' SERIES

# Wood-Frame Construction Problems



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# Wood-Frame Construction Problems

The material for this publication was developed in consultation with the Canadian Home Builders' Association for a series of builders' workshops held across the country.

Cette publication est aussi disponible en français sous le titre *Problèmes de la construction à ossature de bois* (LNH 6073)

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# Introduction

This guide is about problems in the construction of wood frame houses. It is written to help builders understand what causes these situations and how to avoid them.

A problem arises when one or more of these situations exists:

- the occupant is at risk
- the building's materials have deteriorated
- there is unacceptable movement of the building's components
- the building's components cannot function as they were intended to
- the building is unsightly.

For the most part, causes and subsequent ways to avoid the problems revolve around detailing or design, the selection of materials, methods of construction, and the behaviour of the occupants.

Information for this guide was compiled from many sources. Acknowledgement goes particularly to the Canadian Wood Council, the National Research Council, and the Canadian Home Builders' Association.

# Moisture and Wood

Wood is a highly versatile, light, strong material that is rigid and tough. It can be worked in a variety of ways and can be easily fastened and finished.

However, wood has some limitations and problems. The greatest of these is moisture.

Water is present in large quantities in trees and in freshly cut (green) lumber. In some species, the moisture content can be as high as 100 percent. In other words, the weight of the water contained in the green lumber is 100 percent of the weight of the wood when it is oven dried.

Drying lumber loses this high moisture content rapidly if the relative humidity of the surrounding air is low. There is little dimensional change to the lumber during the initial moisture-loss period as the large cells empty their water content. When they are emptied and the fibre cell walls are still saturated with water, a condition known as the fibre saturation point has been reached. This usually occurs when the moisture content is approximately 25 percent. Once the moisture content has stabilized, the equilibrium moisture content (EMC) point has been reached. For example, the EMC of wood is approximately 15 percent when the relative humidity is 75 percent and the temperature is 21° C (70°F). See fig. 1.

In this document, dry wood is defined as having a moisture content of 19 percent or less, green lumber as having a moisture content of more than 19 percent.

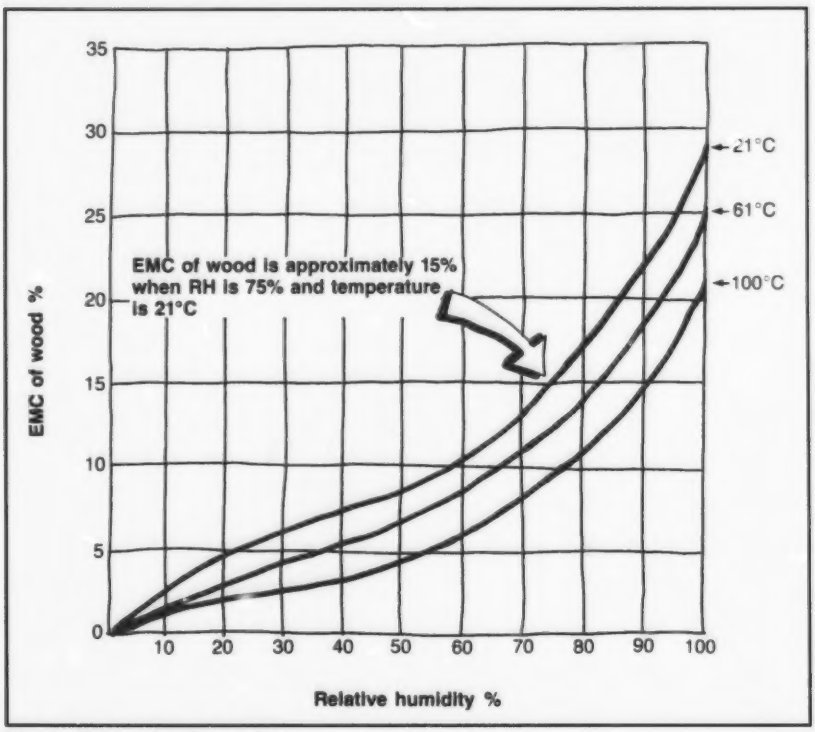


Fig. 1. Fibre saturation point.

### Dimensional Change

Below the fibre saturation point, lumber shrinks and swells as moisture enters and leaves the wood. The Canadian Wood Council suggests that, "if wood is dried from the fibre saturation point to 19 percent average moisture content, lumber shrinks about 2.35 percent in thickness and 2.8 percent in width." On a board 235 mm wide (9½") this would give a shrinkage of 6 mm (¼"). Drying has very little effect on the length of lumber.

As wood dries out, internal stresses are created. These cause the wood to warp, bow, cup, twist, and check (fig. 2).

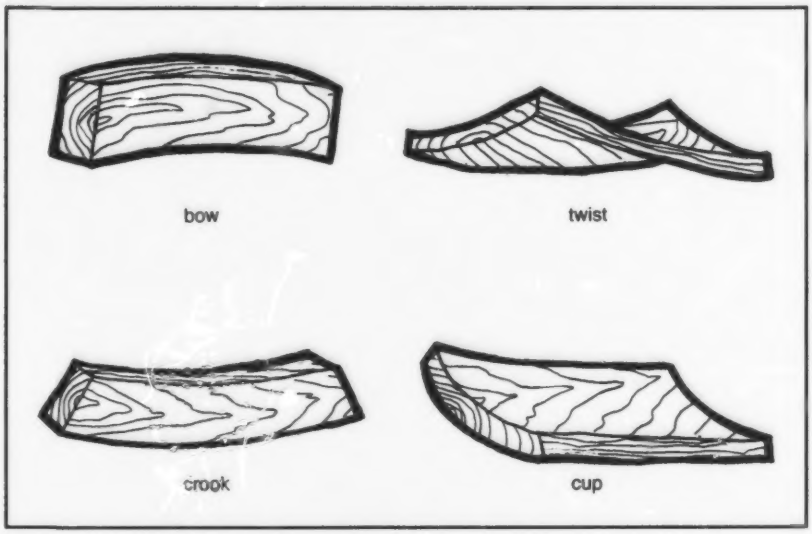


Fig. 2. As wood dries out, internal stresses are created.

### Decay Caused by Condensation

Fungi attack cellulose in the cell walls of wood when three conditions exist: moisture, the presence of air, and an optimum temperature range of 20 to 30°C (68 to 86°F). If any one of these conditions does not exist, the growth of fungi is retarded. The creation of a moisture-free environment is the best way to prevent decay. Most fungi cannot reproduce when the moisture content of lumber is less than 20 percent.

Condensation forms in the wall cavity when moisture-laden air moves into the wall and contacts a surface which is below the dew point temperature of the inside air.

The section on wall framing explores methods of dealing with these situations.

### Precautions for Handling and Storing Wood

The following basic precautions are recommended by the Canadian Wood Council to help diminish the effects of moisture on lumber:

- Protect lumber from free-standing water, rain, snow or ponding.
- Do not store lumber adjacent to moisture sources on the job: bare ground, concrete floors, or freshly plastered surfaces.
- Keep the original wrappings on the lumber, and sealed.
- Promote ventilation by keeping piles well separated with sticks between lumber layers.
- Protect from direct sunlight.
- Store the pieces flat, with sufficient supports; wood tends to take a permanent set when deformed for long periods of time.
- Restrain thin or long pieces of wood in piles by packaging or weighting down; thin pieces deform more than thick pieces, and long pieces are more likely to deform than short pieces.
- If wood must be stored on end, provide sufficient supports and rotate pieces end over end periodically.

# Floor Framing

The components of a wood-framed floor are sills, beams, joists, and sub-flooring. Openings are framed with header and trimmer joists, and cantilevered platforms are often used to construct projections. Problems that might occur in any of these components are described below, together with probable causes and suitable solutions.

## Exterior Sills

Exterior sill plates are lumber 38 × 89 mm (2 × 4) or wider laid flat and anchored to the foundation wall to provide full and even bearing for joists, and to tie the superstructure to the foundation.

### Problem

Lateral movement or lifting of superstructure.

Failure to provide a strong connection between the building frame and the foundation by means of a well–anchored sill plate could result in lateral movement or lifting during high wind conditions.

### Causes

Lack of anchor bolts.

Substitution of nails for anchor bolts.

Improperly positioned bolts that require gouging of the sill plate to set nuts and washers.

### Solutions

- Make sure that sills are properly anchored to the foundation wall. Look at building codes for the size and spacing of anchor bolts. According to the Canadian Wood Council they should be steel bolts approximately 12.7 mm (½″) in diameter, cast into the foundation at 2400 mm (8′) on centres tc an embedded depth of at least 100 mm (4″). See fig. 3. Bolt sills to the foundation wall and make sure that anchor bolts do not lift when you tighten them. In some locations, joists are cast directly into the concrete foundation walls.

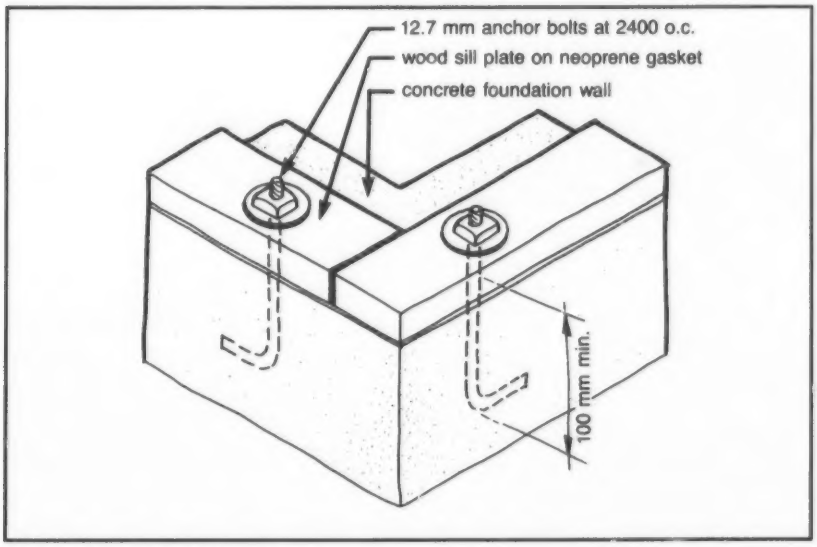


Fig. 3. A properly anchored sill.

## Problem

Physical deterioration of sill plates and headers.

Sill plates and headers rot from fungus attack when three conditions exist: moisture, air, and an optimum temperature range between 20 and 30°C (68 to 86°F). Continued deterioration of the sill and header can result in serious structural problems.

## Causes

Condensation forming at the sill as a result of warm moist air from inside coming into contact with the sill plate and header. Condensation forms when these members have a temperature less than the dew point temperature of the inside air.

Rain penetration from the exterior wall surface to the sill plate and headers.

Capillary action that allows moisture to travel up the foundation wall and into the plate.

## Solutions

*Condensation*

- Isolate the sill from exposure to moist warm air from the interior by means of a continuous air and vapour barrier. At the same time, provide a gasket between the sill plate and the foundation wall (fig. 4). Refer to CMHC's publication *Moisture Problems*.

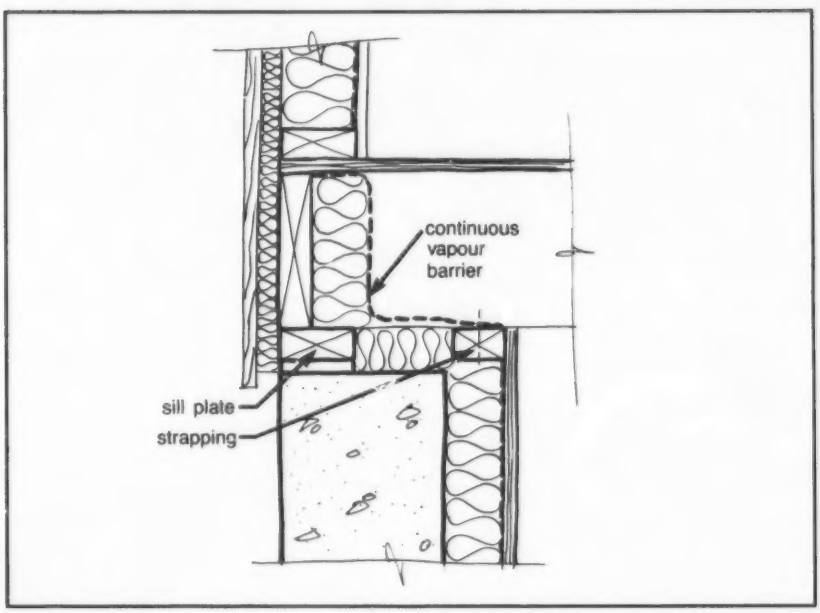


Fig. 4. Continuous vapour barrier isolates the sill plate from warm moist air.

*Rain penetration*

- Provide flashing at the top of the foundation wall extending vertically in the wall cavity so that the flow of rain water or condensation down the sheathing membrane is prevented from reaching the sill plate and is drained to the exterior (fig. 4). With brick veneer, ensure that weepholes at 800 mm (32") on centre are not blocked.

*Capillary action*

- Provide a dampproof course of type S rolled roofing or 0.15 mm (6 mil) polyethylene between the sill and the foundation wall. This creates a moisture barrier that blocks the rise of moisture through the wall.

# Beams and Supports

Floor beams provide intermediate support for joists that cannot span from foundation wall to foundation wall. They can be fabricated from steel or from wood. In the case of wood, the most common is the built-up wood beam. This is usually made up of three or more pieces of lumber 38 mm (1½") thick, set on edge and nailed together from each side.

## Problem

Excessive beam deflection or deformation.

Improperly constructed built-up beams create excessive beam and floor deflection, twisting and beam deformation and cracking of attached surface finishes.

## Causes

Excessive spans.

Poor butt joint positioning.

Improper nailing of individual beam members.

## Solutions

*Excessive spans*

- The design of a built-up wood beam is a function of the length of the span in conjunction with the type and grade of lumber and the expected loading. To determine the size of the beam and the maximum span permitted, make sure you use the span tables found in Building Codes.

*Poor butt joint positioning*

- Make sure you follow the codes that govern the positioning of the butt joints of the individual members of the beam. According to the Canadian Wood Council, "Joints should occur over a support or, for continuous span beams, within 150 mm (6") of clear span quarter points near interior supports... Joints located near quarter points should not reduce the effective width of the beam by more than one half and should not occur in adjacent members at the same quarter point. Only one butt joint may occur in any individual member of a built-up beam within any one span." (See fig. 5).

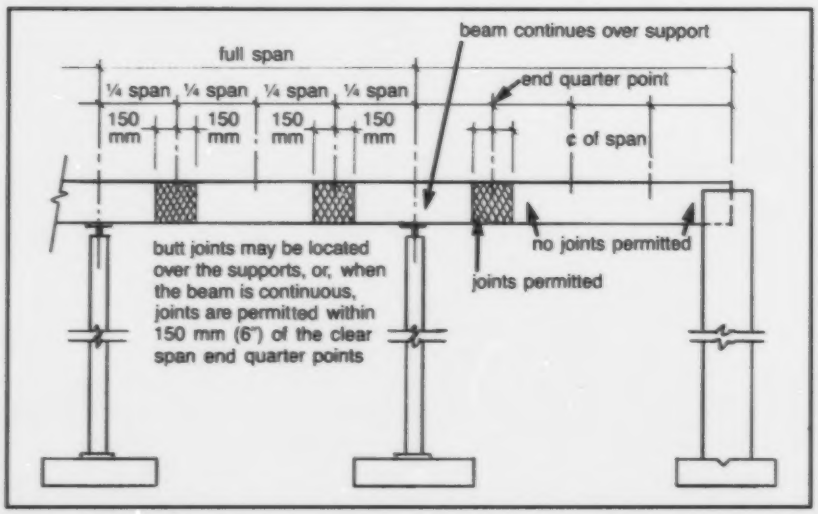
beam continues over support
full span
¼ span
¼ span
¼ span
¼ span
end quarter point
150 mm
150 mm
150 mm
150 mm
℄ of span
butt joints may be located over the supports, or, when the beam is continuous, joints are permitted within 150 mm (6") of the clear span end quarter points
no joints permitted
joints permitted

Fig. 5. Joints may be located over supports, or at or within 150 mm (6") of the end quarter points of the clear span.

*Improper nailing*

- Use the correct procedure for nailing, as stated in codes. Correct fastenings on built-up beams permit the individual members to act in unison, thus creating the qualities of a solid member. Nail the individual members from each side, with a double row of 89 mm (3½") nails spaced at 450 mm (18") apart in each row, and have nails 100–150 mm (4–6") from the end of each piece (fig. 6).

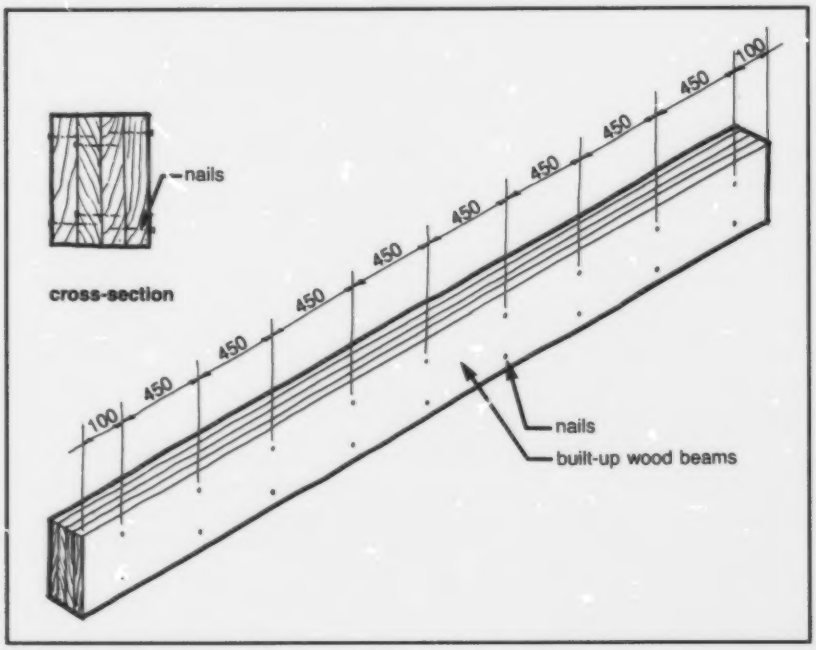


Fig. 6. Correct nailing.

## Problem

Weakened floor assembly because of improper bearing conditions for beams.

Bearing conditions for beams that are poorly designed and built may cause beam failure.

## Causes

Inadequate beam end bearing area.

Beam ends rotting because of moisture.

Bearing on shims or scrap wood.

## Solutions

*Inadequate beam end bearing*

- Make sure that at least 90 mm (3½") of the beam end bears evenly on the support. Where built-up beams butt over a centre post, the bearing must be 90 mm (3½") minimum for each beam end (fig. 7).

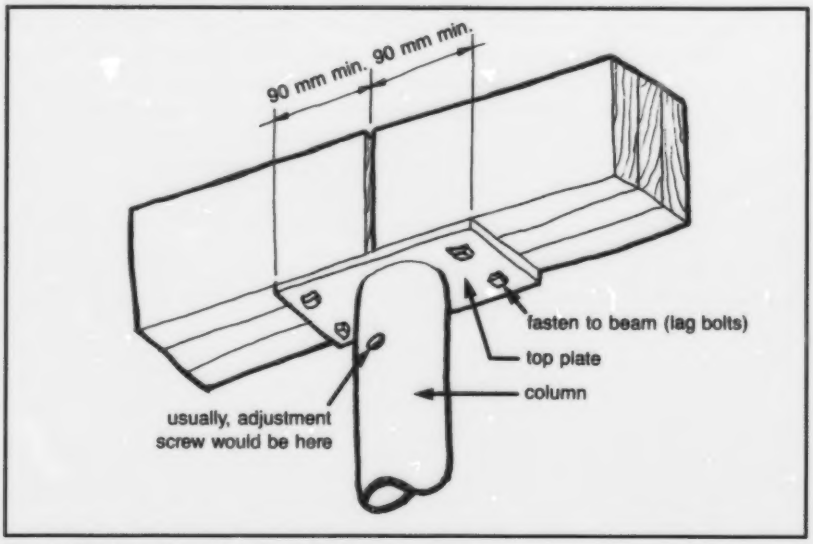


Fig. 7. Beam end must bear evenly on support.

*Rotting beam ends*

- Protect beam ends that bear on exterior foundation walls at or below grade from moisture-induced rotting. Use pressure-treated lumber or provide a 12 mm (½") air space all round the beam end. The space permits air circulation and moisture evaporation (fig. 8).

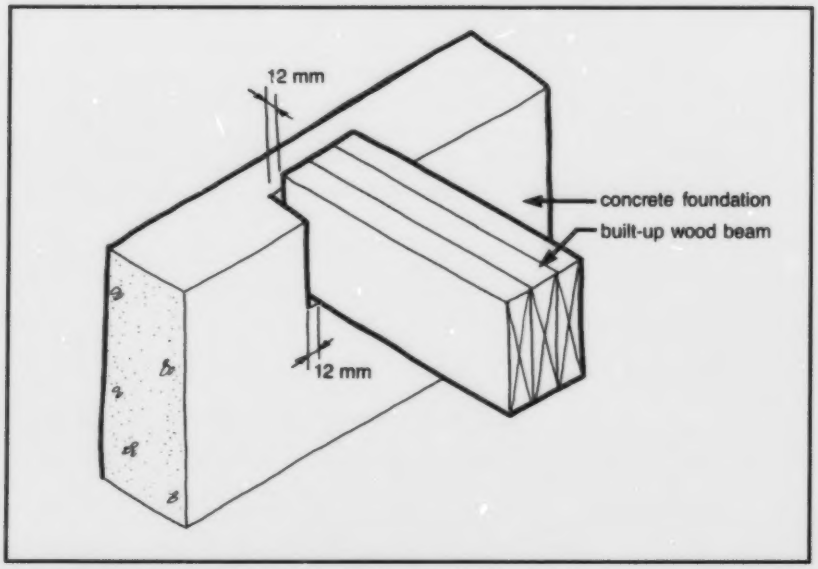


Fig. 8. Protect beam ends from moisture with air space.

*Bearing on shims or scrap lumber*

- Do not use wood shims or scrap to support beam ends to compensate for errors in construction. The beam ends may sink as the blocking shrinks. The best bearing is provided on stable, flat material that has the strength necessary to support the load — steel plates, or masonry, for example.

## Problem

Risk of beam failure because of poor beam support.

Built-up beams can be supported on masonry walls, load–bearing partitions, wood columns or adjustable steel columns. Problems occur when these supports are improperly designed and constructed. Symptoms include excessive bending or twisting of the beam which could lead to possible beam failure.

## Causes

Wood columns narrower than the beam they support, built of short scrap pieces of lumber and not cut square at the top of the column.

Columns placed off-centre on the footing.

Steel column bearing plates smaller than the beam thickness.

## Solutions

*Wood columns*

- Make structurally sound built-up wood columns from continuous pieces of 38 mm (1½") lumber nailed together by 82 mm (3½") nails approximately 300 mm (12") on centre. This causes all the individual members to act together as a continuous structural element. Short lengths of lumber weaken this continuity and cause the risk of column deformation. The columns must also be at least as wide as the beams they support.

*Columns on footings*

- Make sure that columns are centred on their footings. When columns are not placed in the centre of footings, the offset loading could cause the column footing to move, thereby causing movement in the column and the beam.

*Steel column bearing plates*

- Make sure that these bearing plates are as wide as the beam they support. A common condition is that they are not. They must be wide enough to give stability to the connection and to prevent the beam being crushed by the bearing plate.

# Joists

Joists provide the structural support for the floor. They span from one foundation wall to another, or to an intermediate support such as a load-bearing partition or beam. Common problems include excessive floor deflection, floor deformation, and creaking.

## Problem

Floor deformation and risk of failure.

Poorly designed and constructed floor joist systems can cause excessive bending or deflection of the floor and, in extreme cases, risk of floor failure.

## Causes

Excessive joist spans.

Improper joist bearing.

Excessive overlap of joists over beams.

Improper notching and drilling.

## Solutions

*Excessive joist spans*

- Use the span tables found in the building codes to determine the joist size, spacing, and maximum span permitted. As with beams, the selection of the joists size is a function of the loading, the length of span and the type and grade of lumber.

*Improper joist bearing*

- There are several bearing conditions for joists, including resting on top of beams, butting into the sides of beams, and bearing on ledger strips (fig. 9). When the bearing surface area is too small or the connectors and fastenings are too weak, builders face the risk of movement of the joists and subsequent sagging of the floor. In extreme cases part of the floor system could fail. Good building practice suggests the following:
  - 38 by 38 mm (1½ × 1½") ledger strips nailed to the beam with two 82 mm (3½") nails between strip and beam at each joist
  - joists resting on solid end supports should have at least 38 mm (1½") of bearing
  - the use of metal joist hangers.

*Overlapping joists over beams*

- Do not allow joists to project more than 50 mm (2") beyond the beam (fig. 10). Bumps in the floor are created by joist ends that overlap beams too much. The bumps are created by the upward movement of the joist end that occurs when the floor is subject to excessive live loading (fig. 11).

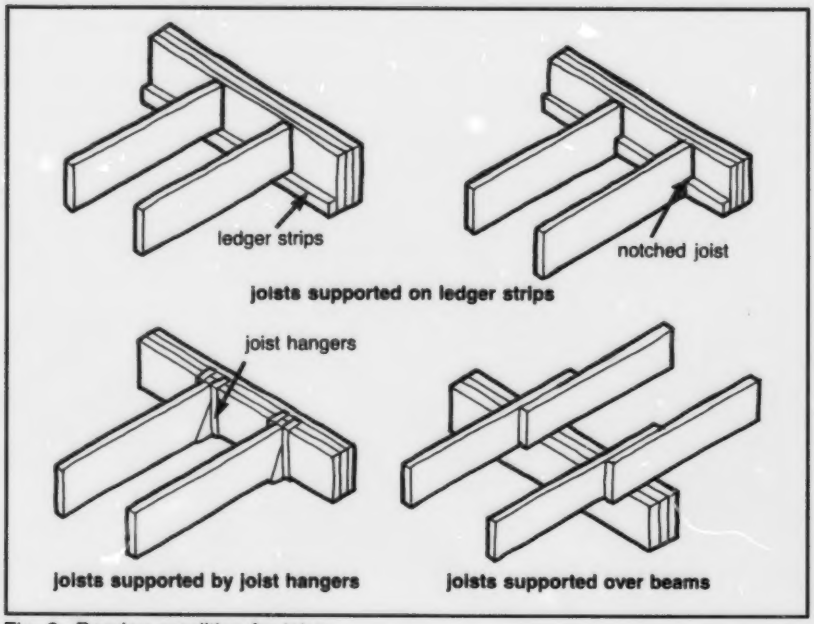


Fig. 9. Bearing condition for joists.

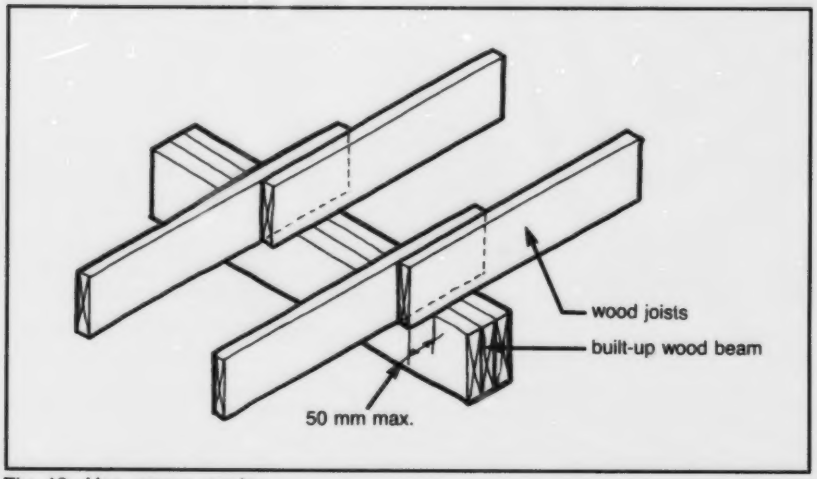


Fig. 10. Use proper overlap.

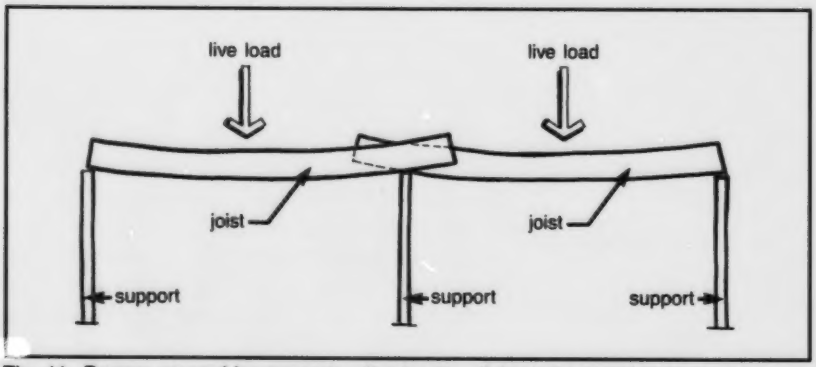


Fig. 11. Bumps caused by excessive live loading if the joists overlap too much.

*Improper notching and drilling*

- Notches, chases, holes and other penetrations through the joist are often required for plumbing, heating or electrical installations. When notching and drilling are done incorrectly, the joist system can be seriously weakened. Keep these holes away from the top or bottom edges and mid-span areas. The joist relies on this material to resist bending (fig. 12).

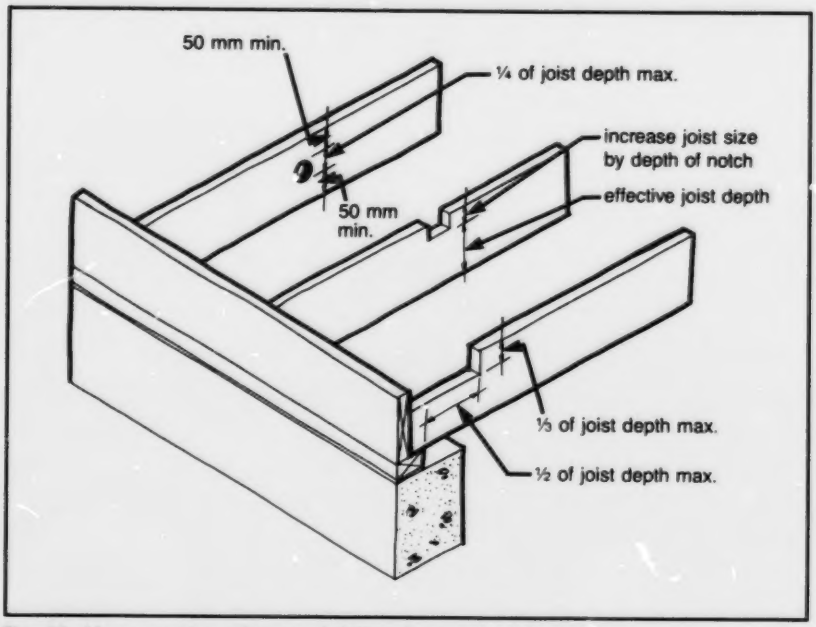
50 mm min.
¼ of joist depth max.
increase joist size by depth of notch
effective joist depth
50 mm min.
⅓ of joist depth max.
½ of joist depth max.

Fig. 12. Use correct notching and drilling for service installations.

## Problem

Excessive floor deflection and spring.

Some floors sag or have excessive bounce when moving live loads are applied.

## Causes

Excessive joist spans.

Inadequate joist bridging or blocking.

Poorly framed openings.

## Solutions

*Excessive joist spans*

- Use the span tables found in the building codes to determine the joist size and maximum span permitted. As with beams, the selection of the right joist size is a function of the length of span in conjunction with the type and grade of lumber.

*Inadequate joist bridging or blocking*

- Make floor systems rigid by the use of lateral restraint members known as blocking or bridging. These elements (fig. 13) in conjunction with toe-nailing and end-nailing at the supports and header joists inhibit joist twisting or rolling. They also transfer live loads to adjacent joists.

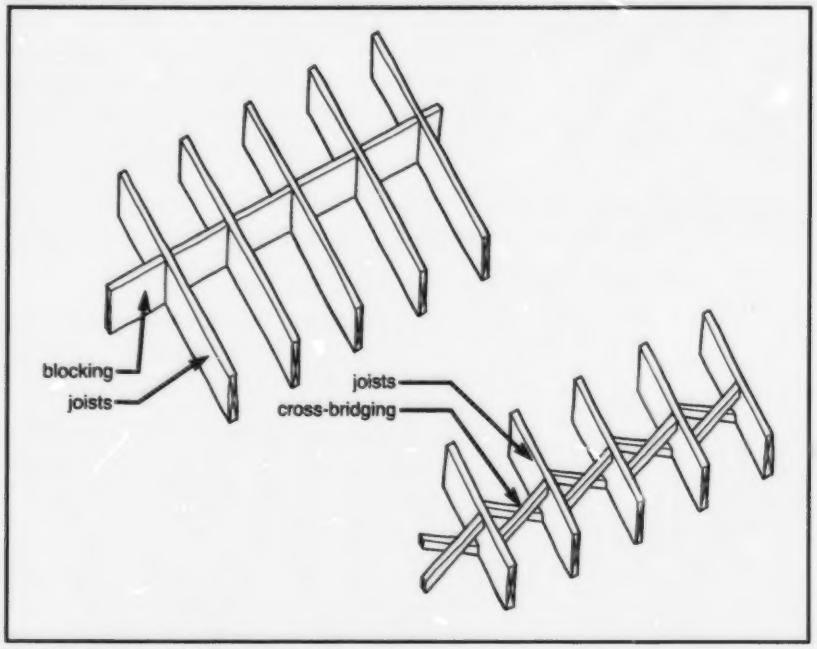


Fig. 13. Ensure rigid floor systems.

The Canadian Wood Council recommends that "multiple bridging consist of 19 mm by 64 mm (¾ × 2½") or 38 mm by 38 mm (1½ × 1½") thick cross bridging nailed into the joist with two 57 mm (2¼") nails." In addition to bridging, minimum 19 mm by 64 mm (¾ × 2½") continuous wood strapping must be nailed to the bottom of each joist and fastened to each end headers and sills.

*Floor Openings*

- Make sure that header and trimmer joists are properly designed and installed, or the framed openings in a floor system can create deflection problems. Best practice suggests:
  - double header joists if longer than 1200 mm (48")
  - double trimmer joists if header is longer than 800 mm (32")
  - joists butted to the framed opening should be supported by joist hangers, ledger strips or end nailing.

## Problem

Creaking floors.

Floors creak as people walk over the surface because parts of the floor system rub against each other owing to differential deflection.

## Causes

Improperly nailed sub-floors.

Insufficient bridging or blocking.

Poor fastening of joists abutting beams.

Nails that should secure the bottom plates of interior partitions go through the sub-floor but not into the joists.

## Solutions

*Improperly nailed sub-floors*

- Ensure that the panel sub-floor is securely fastened to the joists so that the edges of the material do not rub against each other causing a creaking sound. Good practice in installing sub-floor reminds builders to:
  - stagger joints parallel to the joist direction for increased rigidity
  - install the plywood with the surface grain perpendicular to the joist direction for additional strength
  - prevent differential deflection between adjacent panels by using tongue and groove panels or by providing a 38 × 38 mm (1½ × 1½") blocking under the joint
  - secure partition bottom plates to joists or blocking
  - use annular ringed nails to provide better resistance against nail popping, particularly when an underlay is not going to be used
  - renail the subfloor just prior to installing the finished floor
  - glue panel sub-floor to joists.

*Insufficient bridging*

- Joist bridging transfers the live load from one joist to another and helps create a rigid floor structure. Without adequate bridging the individual joists are free to move independently. When this independent movement occurs, differential deflection also occurs, causing creaking. See the previous problem, "Excessive floor deflection and spring," for suggestions on good building practice.

*Poor fastening of joists abutting beams*

- Without proper fastenings (joist hangers tying joists to beams), the differential deflection of the joist and the beam causes the end grain of the joist to rub against the face of the beam. See the previous section "Beams and Supports."

# Cantilever Platforms

Floor joists are often cantilevered past the foundation wall or lower floor exterior walls to gain additional floor area or to frame a platform for bay windows.

## Problem

Platform deflection.

The load deflects the cantilever platform downwards creating cracking on interior surface finishes.

## Causes

Excessive cantilever spans.

Improper tail joist length.

## Solutions

*Excessive cantilever spans*

- As with all structural components in a wood-framed house, you must use building codes to determine joist size. As a guide, the Canadian Wood Council recommends that floor joists supporting roof loads must not be cantilevered "beyond supports a distance greater than 400 mm (16") for 38 × 184 mm (2 × 8) joists, or 600 mm (24") for joists 38 by 235 mm (2 × 10)."

*Improper tail joist length*

- Make sure that the tail joists extend inward a distance at least six times the length of the cantilever measured from the support (fig. 14). Note that this is required only where cantilevers are at right angles to the main floor joists.

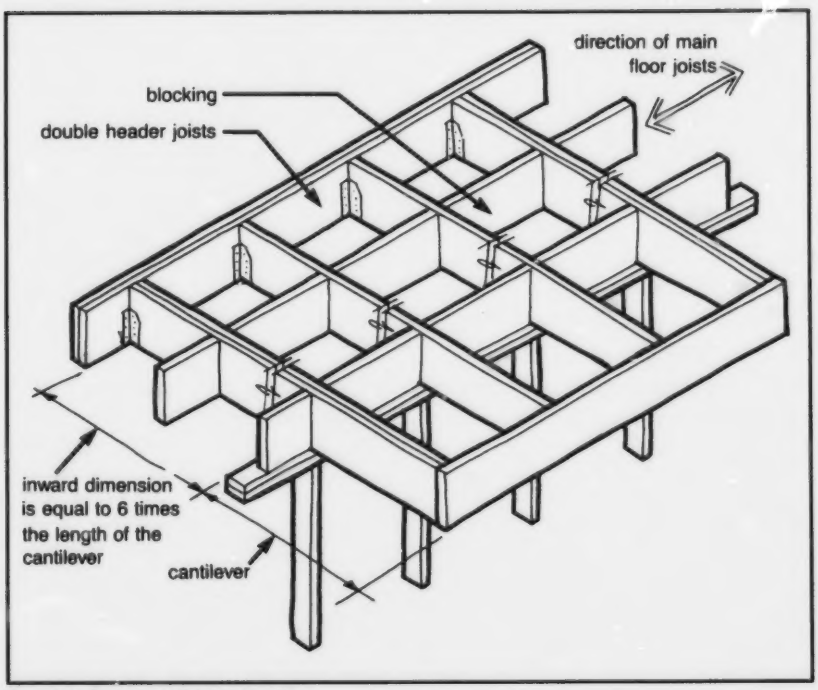
direction of main floor joists
blocking
double header joists
inward dimension is equal to 6 times the length of the cantilever
cantilever

Fig. 14. Proper tail joist length.

## Problem

Adjacent floor deformation.

The floor surface above the interior end of the tail joist is raised and deformed because of the leverage of the cantilever loading. (fig. 15).

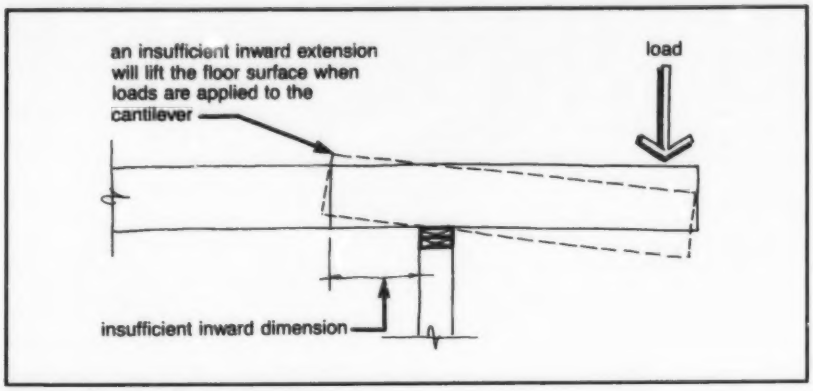
an insufficient inward extension will lift the floor surface when loads are applied to the cantilever
load
insufficient inward dimension

Fig. 15. Avoiding floor deformation.

## Causes

Improper length and fastening of the tail joists.

## Solutions

- When cantilevers are at right angles to the main floor joists, extend the tail joist (fig. 14) back into the floor framing to a length that is at least six times the cantilever.

# Wall Framing

In a wood-framed house, wall framing refers to studs, plates, interior partitions and wall sheathing. It also refers to the framing of wall openings with lintels and jack studs.

There are two basic types of wall framing. The first, platform framing, consists of a series of floor platforms built in sequence and separated by walls.

The second, balloon framing, differs from platform framing in that the exterior wall frames are continuous over several floors. Platform framing is the most common type.

Problems related to wall framing, organized according to the components of the wall system (wall studs and plates, framed openings, and wall sheathing), are described below, together with probable causes and suitable solutions.

## Wall Studs and Plates

Framed walls consist of vertical studs and horizontal top and bottom plates. They support ceiling, floor, and roof structures and act as a framework for the application of insulation and interior and exterior wall materials.

### Problem

Physical deterioration of studs and plates from condensation in the wall cavity.

Wall studs and plates rot from fungi attack when these three conditions exist over an extended period of time: moisture, air and an optimum temperature range between 20° and 30° C (68 and 86°F). This deterioration can proceed to the point of structural collapse.

### Causes

Condensation forms in the wall cavity as a result of vapour diffusion and/or air leakage from inside coming in contact with a surface below its dew point temperature. Vapour diffusion occurs when water vapour is forced through materials. Air leakage is the movement of air carrying water vapour through cracks or holes in the building envelope.

The common causes of water vapour penetration are related to improper installation of the air barrier. This includes discontinuity at openings and around electrical boxes, and the presence of gaps through which air can leak into the wall cavity.

Rain penetration into the wall cavity by direct gravity capillary action or pressure differences can also cause moisture conditions conducive to the growth of fungi.

## Solutions

*Condensation*

- Reduce the amount of humid indoor air from penetrating into the wall cavity and condensing into a liquid by creating an airtight barrier in the wall structure. When polyethylene is used, totally cover the windows and doors with this vapour barrier and cut out later. Staple or tape the vapour barrier to the window and door frames and not to the wall framing around them (fig. 16). CMHC's publication *Moisture Problems* provides builders with details on how to construct air barriers that are continuous, strong and rigid, resist air flow and are durable and easy to maintain. Builders should also advise homeowners to increase house ventilation and use dehumidifiers to help with this problem.

*Rain penetration*

- Prevent conditions that permit water penetration. Walls leak when water is present, openings are available and there is sufficient force to move the water inwards. The absence of any one of these conditions eliminates the penetration of rain water.

The provision of a rain-screen wall is the most effective way of preventing this problem. Refer to CMHC's publication *Moisture Problems* for details on the method of construction.

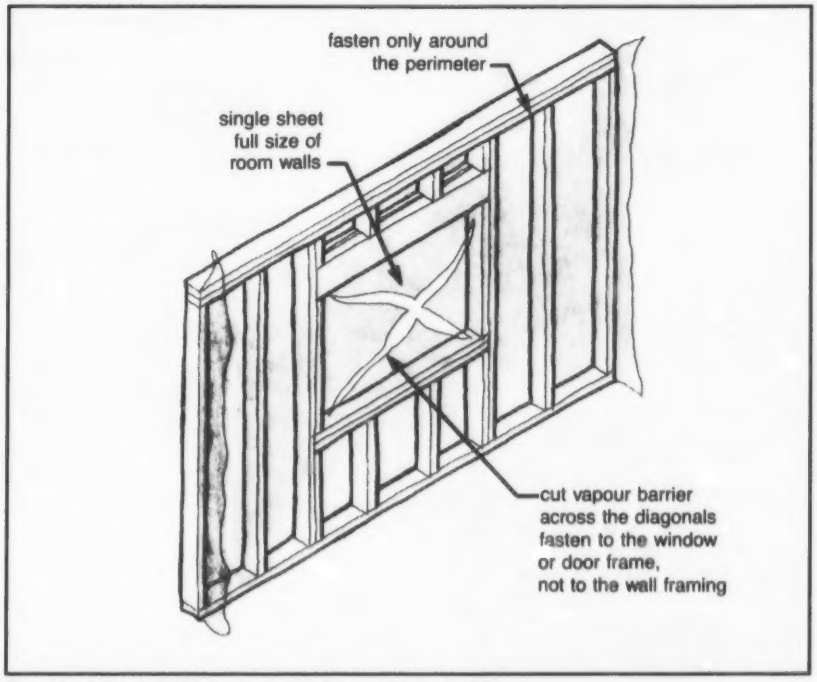


Fig. 16. Use polyethylene to create a vapour barrier.

## Problem

Wall deformation caused by shrinkage.

As framing lumber dries, it shrinks and undergoes internal stresses that cause the wood members to warp, bow, cup, twist and check. Other symptoms of lumber drying are popping nails and cracked drywall.

## Causes

Green lumber.

Poor site storage and handling of lumber.

Excessive moisture generated during the construction phase.

## Solutions

*Green lumber*

- Use dry lumber with a moisture content not greater than 19 percent. Many lumber yards in the country have been found to have lumber with very high moisture content – select lumber carefully.

*Poor site storage and handling of lumber*

- See the section, "Precautions for Handling and Storing Wood."

*Excessive moisture generated during construction phase*

- Follow the precautions listed below to avoid generating excessive moisture during construction:
  - avoid unvented propane or gas heaters because they produce excessive moisture
  - use dry construction materials
  - store lumber close to where it will be used and protect it from rain
  - provide as much natural and mechanical ventilation as possible during construction
  - keep lumber away from direct sunlight.

*Corrective measures to ensure frame is straight*

- Inspect the framing after it been constructed to determine whether it is level, plumb and true. Use the following steps to correct problems:
  - provide blocking between studs that bow sideways (fig. 17)

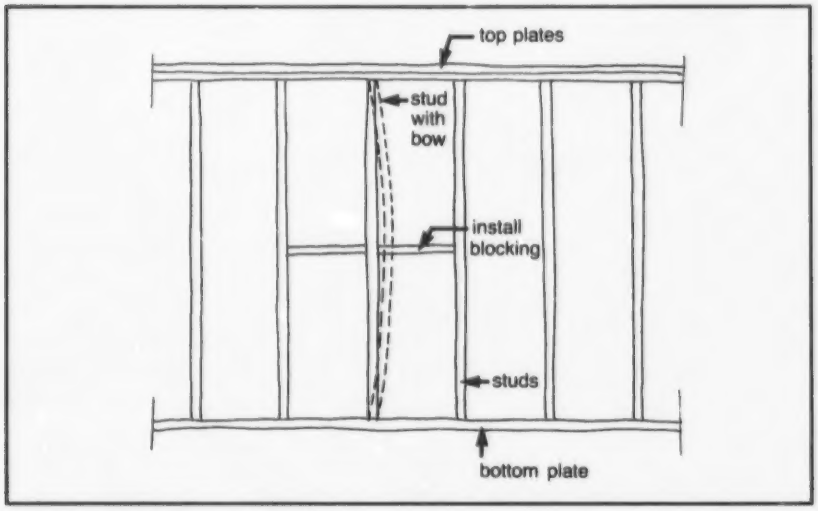


Fig. 17. Prevent or correct "bowing."

- straighten warped studs (crowns) by saw-cutting the concave or hollow sides and driving in wedges; provide nailing scabs to reinforce the cut stud (fig. 18)
- although studs shrink very little in length, check that they all reach the top plates — if they do not, install hardwood shims to fill the space (do not use cedar shims — they are easily crushed and do not provide adequate bearing strength).

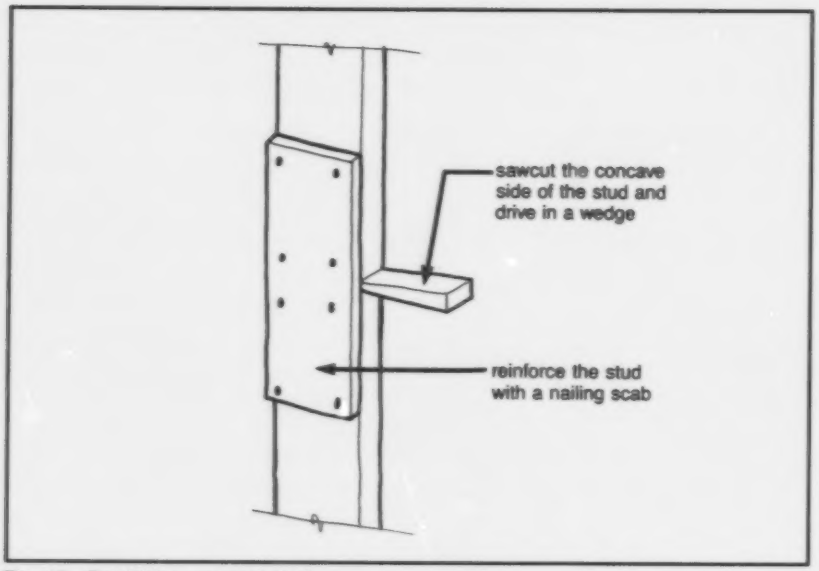


Fig. 18. Straighten warped studs

## Problem

Weakened wall studs.

Weakened studs can result in distortion of the frame and cracked surface finishes.

## Causes

Studs not installed plumb.

Excessive notching and drilling of bearing studs.

## Solutions

*Studs not installed plumb*

- Take care that studs are aligned square. Measure the diagonals of the framing to ensure that the dimensions are equal before it is lifted into place. Install a cross brace at 45 degrees let into the studs, or install wall sheathing before erecting the walls.

*Excessive notching and drilling of bearing studs*

- Notches, chases, holes and other penetrations through bearing studs are often required for electrical, plumbing or heating installations. Should this be the case, follow these recommendations:
  - for studs that have been notched or drilled by more than one third their depth, reinforce with 38 mm (1½") lumber nailed to the side of the studs and extending 600 mm (24") on each side of the notch or hole
  - reinforce notched top plates in the same fashion if less than 50 mm (2") in width remains.

**Note:** If the face of the stud or plate must be reinforced, sheet metal is usually installed to allow a wall finish to be applied over it.

## Problem

Excessive heat loss from thermal bridging.

Thermal bridges occur when exterior wall studs and plates are arranged to encourage the transmission of heat through walls. This can cause localized condensation, mildew growth and dust marking. It also increases the costs of heating and cooling the house.

## Causes

The selection of an exterior wall stud spacing that maximizes framing materials and minimizes insulation.

Corner and partition intersection details that increase the amount of framing and decrease the insulation used.

## Solutions

*Exterior wall stud spacing*

- Use the maximum permitted by codes to reduce the number of studs, that is, thermal bridge conditions. Consider the strapped wall, staggered stud wall, or double stud wall system as methods of increasing the thermal resistance of the wall (fig. 19).

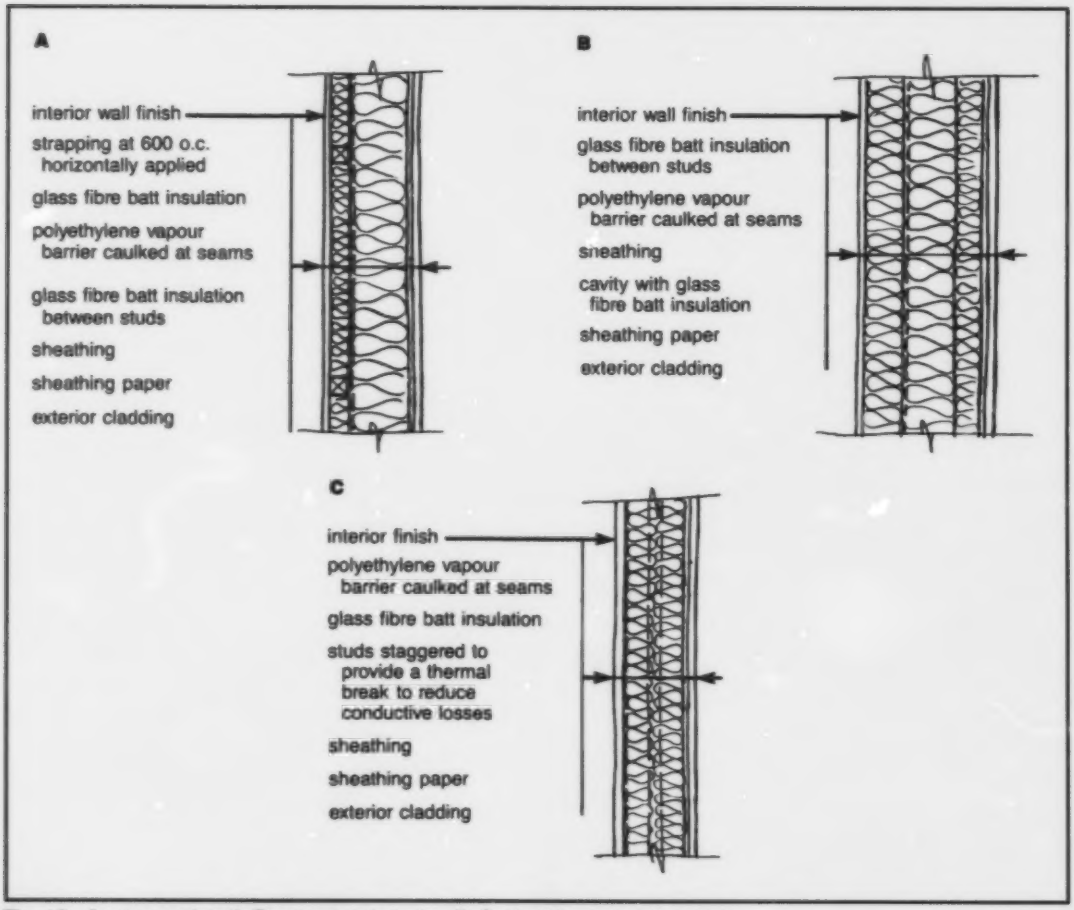


Fig. 19. A: strapped wall; B: staggered stud wall; C: double-stud wall system.

*Corners and partition intersections*

- Use corner and partition intersection details that reduce the number of wood framing members. This will cut down the passage of heat, particularly when the wall is well insulated (fig. 20).

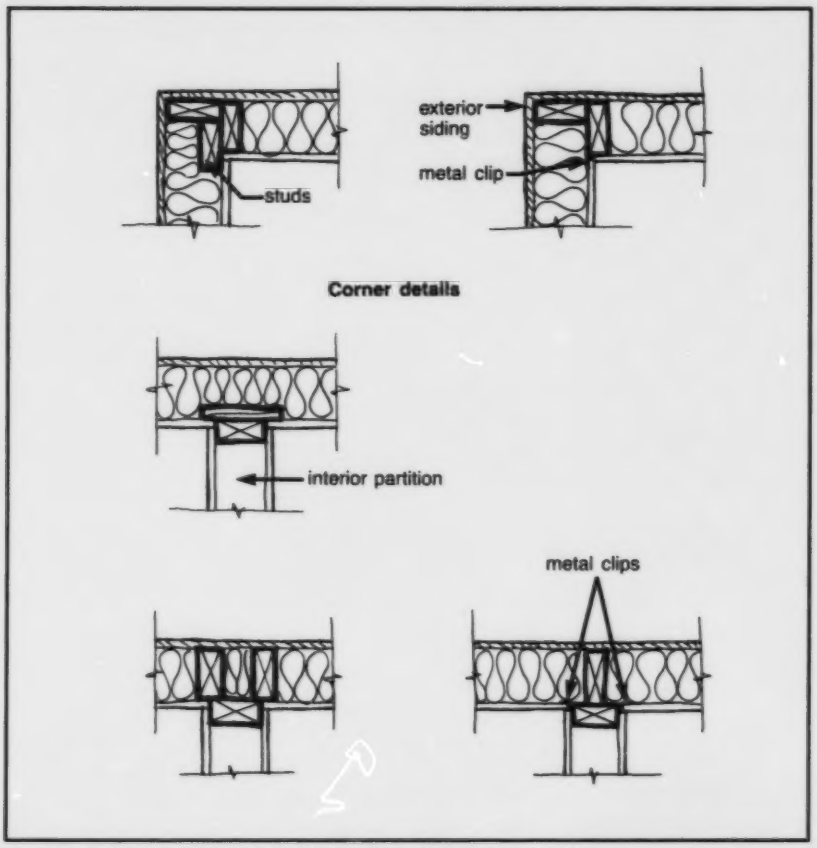


Fig. 20. Exterior wall and interior partition intersection.

*Exterior insulated sheathing*

- Many builders now install exterior insulated sheathing between the exterior wall frame and the exterior finish to provide an additional thermal break.

## Problem

Risk of fire spread.

Failure to provide the required framing members (in balloon frame construction) for a fire stop could result in the spread of fire or smoke between floors in the case of fire. Other related symptoms may include unwanted air or noise travelling between floors.

## Cause

Lack of fire stops, or inadequate fire stops that are not continuous.

## Solution

*Inadequate fire stops*

- Install fire stops in balloon frame construction with 38 mm (1½") thick lumber blocking between the studs, at floor and ceiling levels (fig. 21). This will eliminate the passages in the wall between floors. Check codes for specific detailed requirements.

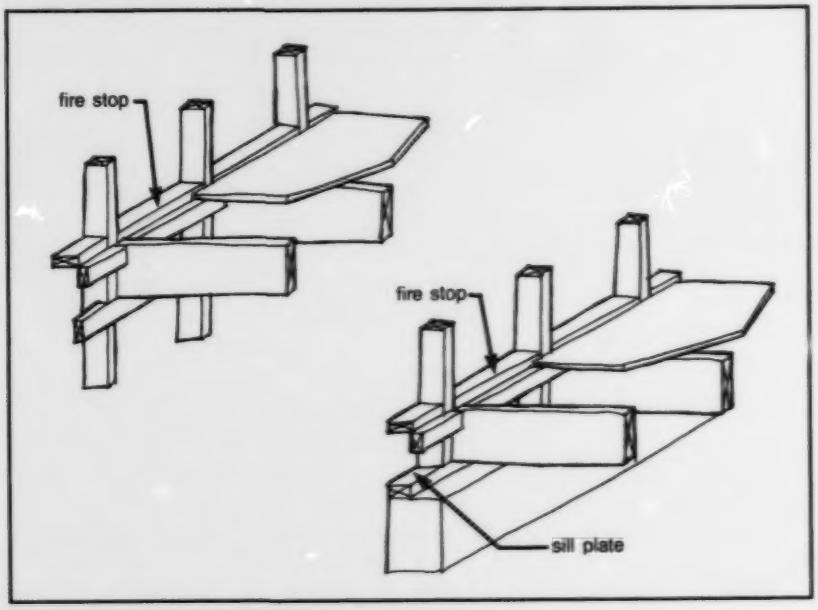


Fig. 21. Fire stops in balloon frame construction.

# Framed Wall Openings

Rough openings for doors and windows are framed at the head by lintels or beams and at the jamb by jack studs.

## Problem

Doors and windows difficult to operate.

Poorly constructed openings in the wall frame can result in windows or doors that are difficult to open or close.

## Causes

Rough openings are too small.

Wall studs are not plumb.

Shrinkage of framing materials.

Deflecting lintels.

## Solutions

*Rough openings*

- Construct openings 25–40 mm (1–1½") wider and 12–20 mm (½–¾") higher than the required size to allow for movement of the framing members. Avoid tightly packed insulation between the opening and the window or door frame.

*Wall studs not plumb*

- Take precautions in constructing studs around openings to ensure that they are plumb and true. Provide a diagonal brace let into the wall frame at 45° to inhibit wall movement.

*Shrinkage of framing materials*

- Use wood with a moisture content that does not exceed 19 percent. Correct problems created by warping and bowing prior to installing finished window and door frames.

*Deflecting lintels*

- Take the following precautions to prevent lintel deflection and the subsequent sticking of doors and windows:
  - avoid eccentric loads over lintels — beams resting on lintels, for example
  - size lintels according to the width of the opening and the vertical loads supported
  - provide full bearing of lintels on jack studs and use continuous jack studs
  - do not use cedar shims to increase the effective length of jack studs (cedar compresses — use hardwood where shims are unavoidable)
  - to help to prevent load transfer to the window or door frame, avoid using shims between the frame head and lintel.

# Wall Sheathing

Sheathing is used on exterior walls and on roof gable ends to add rigidity to the frame, and when there is a need for a rigid material for intermediate fastening between studs.

## Problem

Disintegration of wall sheathing.

Wall sheathing rots from fungi attack when three conditions exist for a prolonged period of time: moisture, air, and an optimum temperature range between 20° and 30°C (68 and 86°F). Water reaches the sheathing either by condensation or by rain penetration.

## Causes

Condensation forming in the wall cavity as a result of vapour diffusion and/or air leakage from inside coming in contact with a surface below its dew point temperature.

Rain penetration into the wall cavity by direct, gravity capillary action or pressure difference forces.

Handling and storage of material.

## Solutions

*Condensation*

- Reduce the amount of humid indoor air from penetrating into the wall cavity and condensing into a liquid by creating an airtight barrier in the wall structure. CMHC's booklet *Moisture Problems* provides builders with details on how to construct air barriers that are continuous, strong and rigid, resist air flow and are durable and easy to maintain. Builders should also advise homeowners to increase house ventilation and use dehumidifiers to help with this problem.

*Rain penetration*

- Walls leak when water is present, openings are available and there is sufficient force to move the water inwards. The absence of any one of these conditions eliminates the penetration of rain water.

The provision of a rain-screen wall is the most effective way of preventing rain penetration. Refer to CMHC's publication *Moisture Problems* for details on the method of construction.

*Handling and storage of materials*

- See the section "Precautions for Handling and Storing Wood."

# Roof Framing

Wood-framed roofs can be either pitched or flat. In wood-frame house construction roof framing consists of ceiling joists, rafters, ridge boards and sheathing. In flat-roof framing the rafters also serve as the ceiling joists. Prefabricated roof trusses are one of the most common method of framing pitched roofs.

## Roof Framing Members

### Problem

Physical deterioration.

Roof members rot when moisture, air and an ambient temperature between 20° and 30°C (68 and 86°F) are present. This deterioration can proceed to a point of structural collapse. Indicators of this problem include:

- growth of mould and mildew on the roof sheathing and roof framing members
- water leaking through the ceiling
- deteriorating interior room finishes
- build-up of wetness or frost on roof members
- roof sheathing sagging
- metal truss plates corroding
- decreased thermal resistance of insulation (wet and compacted, especially around electrical openings, partition walls, stack-pipe opening, and chimneys)
- icicles under the soffit area and around roof vents
- paint peeling on the ceiling or in the soffit area.

### Causes

Condensation forming in the attic because of warm moist air seeping up from indoors and coming in contact with the framing members. The air condenses because the dew point temperature is greater than the temperature of the wood members. The air seeps up from the indoors as a result of vapour diffusion or air leakage. Vapour diffusion is water penetrating through materials and air leakage is the movement of air carrying water vapour through cracks or holes in the building envelope.

Rain penetration through the roofing materials.

Snow blowing into the attic.

Inadequate ventilation that does not allow attic moisture to be carried away or absorbed.

### Solutions

*Condensation in the attic*

- Reduce the amount of humid indoor air from penetrating into the attic and condensing into a liquid by creating an airtight barrier in the wall structure. CMHC's booklet *Moisture Problems* provides builders with details on how to construct air barriers that are continuous, strong and rigid, resist air flow and are durable and easy to maintain. Builders should also advise homeowners to increase house ventilation and use dehumidifiers to help with this problem.

*Rain penetration*

- The elimination of rain water penetration in roofs is discussed in another CMHC publication, *Roofing and Flashing Problems*.

*Snow blowing into the attic*

- Install baffles in soffits, and vents with screen filters (fig. 22). This will also prevent the insulation from being displaced or penetrated by the wind.

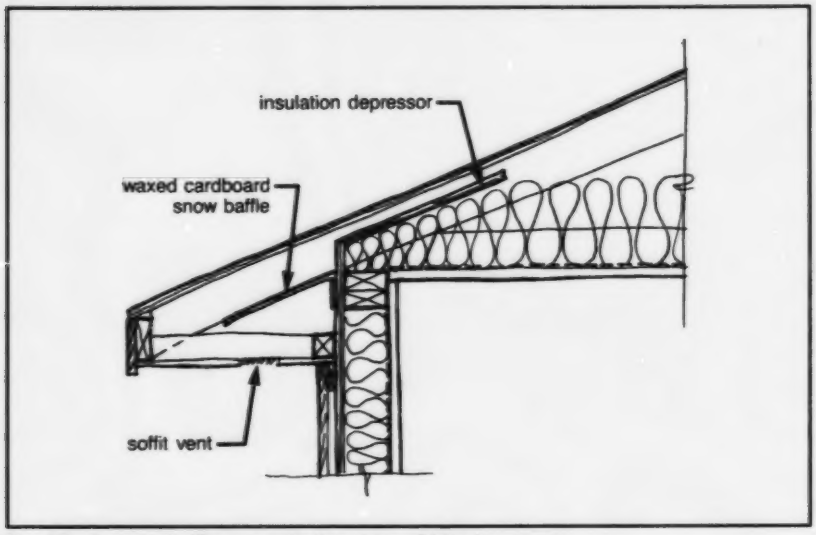


Fig. 22. A snow baffle prevents the entry of blowing snow.

*Inadequate ventilation*

- Ensure that the vent area is at least 1:300 of the ceiling area for most roofs, or 1:150 for low slopes; that is, for every 300 $m^2$ (3200 $ft^2$) of ceiling, 1 $m^2$ (10.75 $ft^2$) of unobstructed ventilation is required. Adjust this ratio to account for the screen coverings over the vents. Use the following table as a guide.

| **Screen Covering** | **Recommended Vent Area ($m^2/m^2$)** |
|---|---|
| 6 mm (¼") hardware cloth | $^1/_{300}$ |
| 6 mm (¼") hardware cloth with rain louvres | $^2/_{300}$ |
| 3 mm (⅛") mesh screen | $^2/_{300}$ |
| 3 mm (⅛") mesh screen with rain louvres | $^{2.5}/_{300}$ |
| 1½ mm (1/16") mesh screen | $^{2.5}/_{300}$ |
| 1½ mm (1/16") mesh screen with rain louvres | $^3/_{300}$ |

- Evenly distribute vents around the building. Half the vent area should be located in the soffit and the other half high on the roof (gable, roof or ridge vents).

- Avoid rendering soffit vents useless. Do not block the area between the wall top plate and the roof sheathing with insulation. Provide a ventilation channel or more insulation by the following means:
  - an insulation depressor or baffle (fig. 23, A)
  - stub end or high heel trusses which allows a full depth of insulation (fig. 23, B)
  - split plastic or cardboard tubes (fig. 23, C).

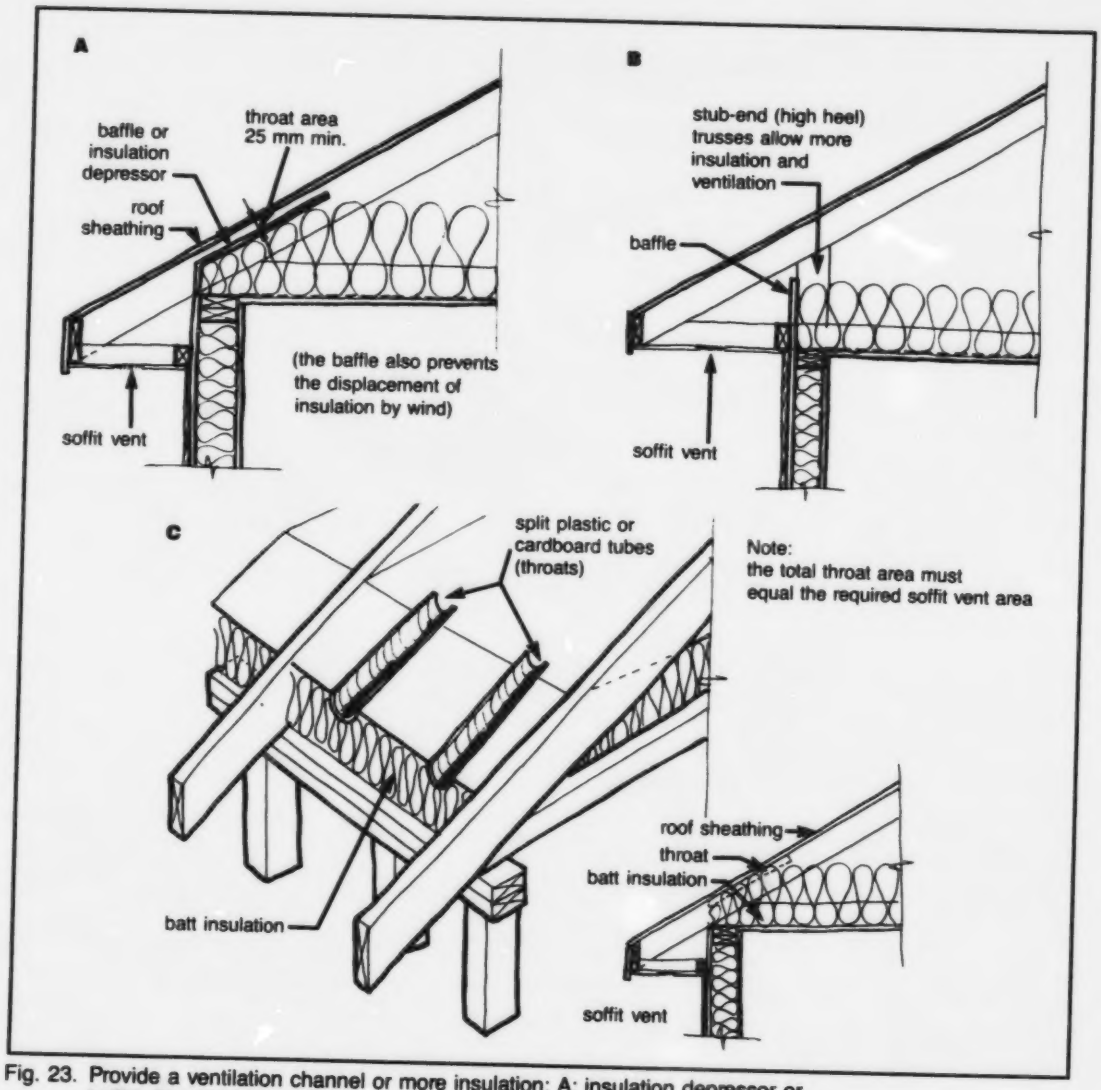


Fig. 23. Provide a ventilation channel or more insulation: A: insulation depressor or baffle; B: stub-end or high heel trusses; C: split plastic or cardboard tubes.

## Problem

Deformation of roof trusses.

Deformation of roof trusses, known as "truss uplift," causes a separation at the intersection of the ceiling and the interior partitions.

## Causes

Differential shrinkage between the top and bottom chords. The bottom chord is insulated and therefore warmer and drier than the top chord. Because of this, the bottom chord is bent upwards as the top chord lengthens as it absorbs moisture (fig. 24).

Fastening of partition top plates to truss bottom chords.

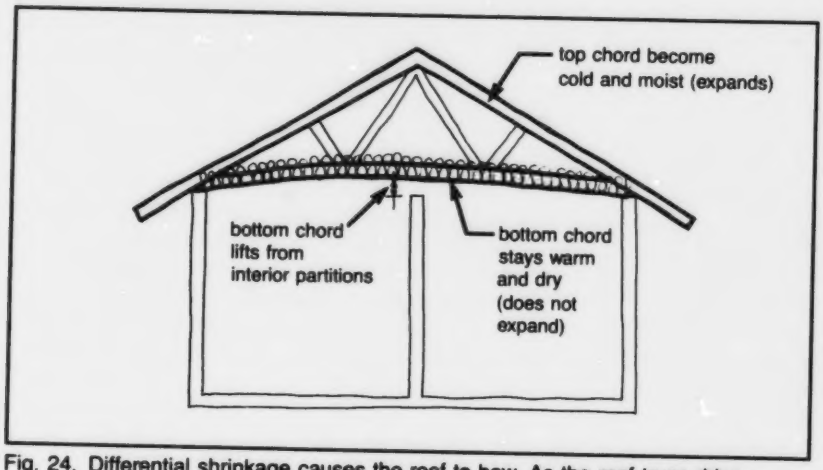
top chord become cold and moist (expands)
bottom chord lifts from interior partitions
bottom chord stays warm and dry (does not expand)

Fig. 24. Differential shrinkage causes the roof to bow. As the roof truss dries, shrinkage occurs. The bottom chord shrinks more than the top chord because it is not exposed to moisture. The top chord may lengthen if it is subjected to excessive moisture.

## Solutions

*Differential shrinkage*

- Ensure that adequate ventilation has been provided for the attic area.
- Ensure that the vents are located so as to provide good air flow through the attic space.
- Minimize the potential for differential shrinkage by the following means:
  - use trusses made from kiln-dried wood
  - store trusses where they will be kept as dry as possible on site
  - sheath the roof as quickly as possible after truss erection
  - ensure airtight ceiling construction to prevent moisture from entering the attic space
  - provide adequate attic ventilation.
- Minimize the length over which truss uplift can occur by using the following:
  - short truss spans aligned with house width rather than house length
  - two monopitch trusses in place of a single long-space truss
  - steeper sloped trusses.

**Note:** Trusses must be securely attached to exterior walls to prevent wind uplift on the roof.

*Fastening of partitions*

- Do not try to prevent truss uplift by fastening the trusses more securely to the partition walls – this may actually lift the walls off the floor. Lightly fasten trusses to partition walls or leave them free standing.
- Use "floating corners" to hide the effects of truss uplift. Fasten both the ceiling drywall and the partition wall drywall away from the corner joint. This technique uses the natural flexibility of drywall to allow uplift of 50–75 mm (2–3") to occur without cracking the corner joint. Recommended minimum float distances are:
  - 300 mm for 13 mm ceilings (12" for ½")
  - 400 mm for 16 mm ceilings (16" for ⅝")
  - 200 mm for partition walls (8" for partition walls).

**Note:** Gypsum manufacturers recommend against floating the ceiling more than 600 mm (24"). For exterior walls, wall panels should be fastened to the top plate for improved cracking resistance and hold-down capacity. See CMHC's *Drywall Application*.

- With floated corners, double the first row of fasteners to prevent pull-through.
- Ensure strong corner joints. Avoid scoring the paper tape with the trowel. Joints made with fibreglass tape are approximately twice as strong as those with paper tape.
- Reduce the stress on corner joints by holding the ceiling drywall to the top plate with drywall clips, with wood blocks or with wider top plates and strapping. Drywall clips can be attached to the ceiling drywall or to the wall framing before the drywall is installed. Clips are usually spaced at 600 mm (24"). Consult manufacturers for recommended installation practices.
- Where partitions run parallel to roof trusses, and where trusses are too close to the partition to permit floating, provide blocking between trusses or use strapping.
- The general use of ceiling strapping is recommended, as it allows maximum float distances, reduces stress on the drywall, and results in flatter ceilings. Types of strapping include 19 × 64 mm (¾ × 2½"), 38 × 38 mm (1½ × 1½") and resilient channels. Strapping can be combined with wider top plates or nailers to hold down the ceiling drywall.
- If truss uplift occurs, drive fasteners through in the ceiling drywall near the corner joint and retape the joint to create a floating corner. Alternatively, you can attach moudlings to the ceiling (not to the walls) to cover the crack at the joint and to create a slip joint. Do not attempt to remedy truss uplift by driving wedges between the trusses and the partition walls. This can cause serious structural problems when the truss settles later.

## Problem

Sheathing sags.

Failure to provide a suitable thickness of roof sheathing panels or inadequate edge support will result in sagging roofs. Other symptoms may include loosened fasteners for shingles or damaged roof coverings, which both result in rain penetration.

## Causes

Sheathing panels too thin to brace the roof frame laterally; and loosening of nails, caused by sheathing bouncing when nailed.

Lack of "H"-clip for blocking edge support when required.

## Solutions

*Sheathing is too thin*

- The thickness of the sheathing panels depends on the joist, rafter or truss spacing, and whether the edges are supported. If the edges are not supported the thickness will need to be greater.

*Inadequate edge support*

- Ensure that all end joints of the panels are on framing members.
- Provide 38 × 38 mm (1½ × 1½") blocking between the roof framing members under the joints running across the frame or install metal H-clips between each sheet under the joints running across the frame. Use one H-clip between each framing member (fig. 25).

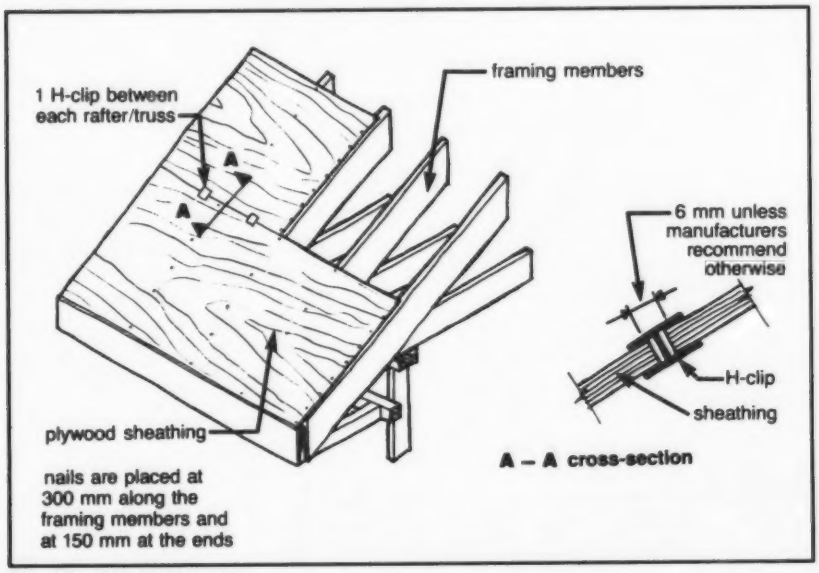
1 H-clip between each rafter/truss
framing members
A
A
6 mm unless manufacturers recommend otherwise
H-clip
sheathing
plywood sheathing
A – A cross-section
nails are placed at 300 mm along the framing members and at 150 mm at the ends

Fig. 25. Use H-clip nails.

# Framed Openings

## Problem

Weakened roof assembly because of inadequate load transfer.

Loads not adequately transferred around openings for skylights may result in a weak roof assembly. Related symptoms may include excessive movement or failure.

## Cause

Roof trusses cut for the construction of skylights without due regard to the pertinent details for transferring the load to the adjacent trusses.

## Solution

*Roof trusses cut carelessly*

- Ensure that double rafters/trusses are used on each side of the opening.
- Install double header joists at each end of the opening, butted against the cut rafters. These will transfer the loads from the cut rafter to the adjoining rafters. A truss hanger on the header joist should be installed to carry the cut rafter (fig. 26).

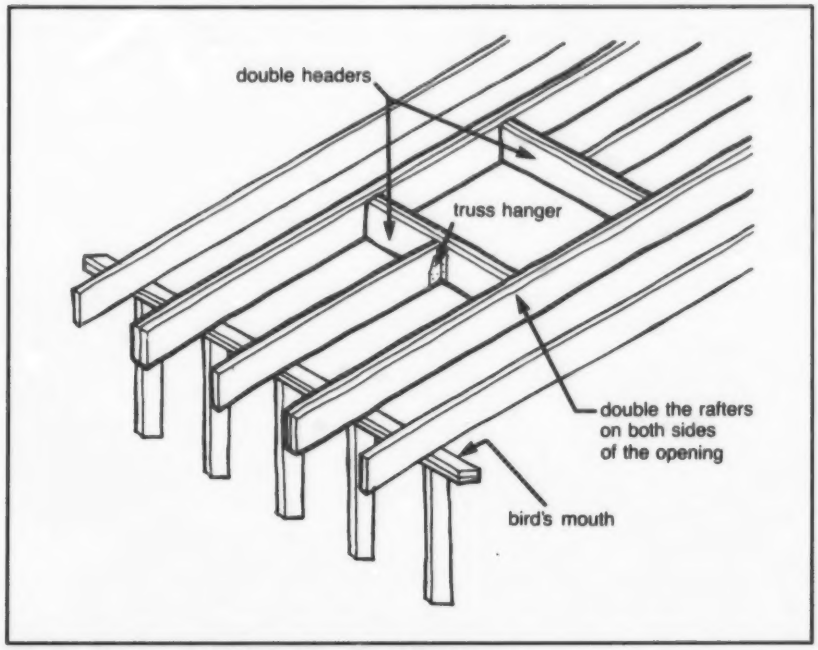


Fig. 26. Use double header joists and truss hangers.

# Flat and Cathedral Ceilings

## Problem

Deterioration of framing members.

Some flat or cathedral ceiling designs do not allow sufficient space to permit adequate ventilation of moist warm air. Water vapour condenses and moisture in combination with air and the right temperature induces rot. Other related symptoms include:

- water leakage through the ceiling
- deterioration of interior room finishes
- decreased thermal resistance of insulation.

## Causes

Insufficient space between the top of the insulation and the underside of the roof sheathing to allow for adequate ventilation of moist warm air.

Inadequate venting of the roof space to the exterior.

## Solutions

*Insufficient space*

- Increase the depth of the flat or cathedral ceiling roof structure by using deeper joists or a truss framing system (fig. 27). An alternative is to use a combination of deeper joists and cross purlins (fig. 28). Both give greater space between the insulation and the underside of the roof sheathing.

*Inadequate venting*

- Locate vents to roof spaces in such a manner as to encourage the flow of air on a continuous basis.

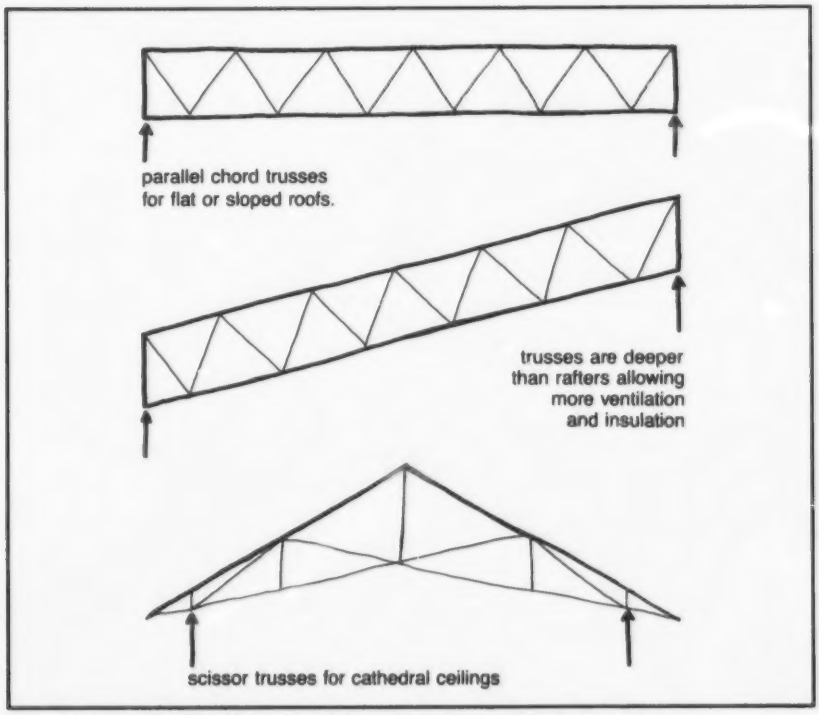


Fig. 27. Increase the depth of a flat or cathedral ceiling roof structure.

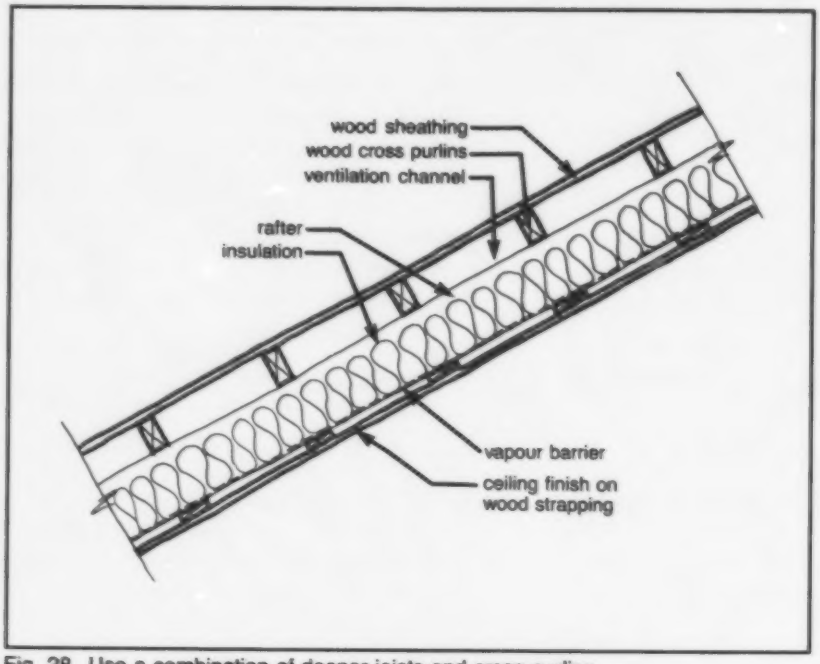


Fig. 28. Use a combination of deeper joists and cross purlins.

# Additional Reading

| Source | Publication |
|---|---|
| Canada Mortgage and Housing Corporation<br>682 Montreal Road<br>Ottawa, Ontario<br>K1A 0P7<br>(613) 748-2000 | *Canadian Wood-Frame House Construction*, 1988<br>NHA 5031<br><br>*Drywall Installation*, 1988<br>NHA 5886<br><br>*Moisture Problems*, 1988<br>NHA 6010<br><br>*Roofing and Flashing Problems*, 1988<br>NHA 6076 |
| Canadian Wood Council<br>55 Metcalfe Street, 15th Floor<br>Ottawa, Ontario<br>K1P 6L5<br>(613) 235-7221 | *Framing Techniques*, 1985<br>CWC Datafile WB-1<br><br>*Storage and Handling*, 1985<br>CWC Datafile CW-1<br><br>*Structure and Properties*, 1986<br>CWC Datafile SP-1 |
| National Research Council of Canada<br>Institute for Research in Construction<br>Publication Section<br>Ottawa, Ontario<br>K1A 0R6<br>(613) 993-2463 | *The Difference Between a Vapour Barrier and an Air Barrier*, 1985<br>BPN 54<br><br>*Humidity, Condensation, Ventilation in Houses*, 1984<br>NRCC 23293<br><br>*Decay of Wood*, 1969<br>CBD 111<br><br>*Vapour Barriers: What Are They? Are They Effective*, 1976<br>CBD 175<br><br>*Moisture Problems In Houses*, 1984<br>CBD 231<br><br>*Effects of Wood Shrinkage in Buildings*, 1987<br>CBD 244 |

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